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From The Field

Influence of Invasive Hybrid Cattails on Habitat Use by Common Loons

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ABSTRACT An invasive hybrid cattail species, *Typha × glauca* (*T. × glauca*), is rapidly expanding across the United States and Canada. Dense clonal stands of *T. × glauca* outcompete native wetland plants, reduce open-water habitats, and negatively affect native wetland plant diversity; however, effects of hybrid cattail expansions on native wildlife are still unclear. We used multiple surveys and single-season occupancy models to examine how the relative coverage of *T. × glauca* affected habitat use by common loons (*Gavia immer*) at 71 wetland sites in Voyageurs National Park, Minnesota, USA, during summer 2016. Delineated wetland sites (2 ha) were considered potential resource patches for common loons and positioned along a gradient of relative *T. × glauca* coverage. Detection of common loons was influenced negatively by the time of day surveys were conducted. Occupancy probabilities were greater at sites with deeper water levels, possibly indicating selection for areas with adequate water depths for pursuit-based foraging for fish. Contrary to our hypothesis, common loons appeared insensitive to the relative coverage of *T. × glauca* at wetland sites. Future research should focus on elucidating potential threshold-effects of *T. × glauca* expansions on additional loon demographic rates. © 2018 The Wildlife Society.

KEY WORDS cattails, common loon, *Gavia immer*, invasive species, *T. × glauca*, Voyageurs National Park, waterbird, wetland management.

Typha × glauca (hereafter, "*T. × glauca*"), a successful hybrid between native broad-leaf cattail (*Typha latifolia*) and invasive narrow-leaf cattail (*Typha angustifolia*), is considered the most invasive *Typha* species in North America (Travis et al. 2010, Larkin et al. 2011, Marburger and Travis 2013). Once established, *T. × glauca* rapidly dominates native vegetation communities by outcompeting native plants for light and nutrient resources because of its physical structure and extensive root system (Travis et al. 2010, 2011). *T. × glauca*'s rapid replacement of native vegetation results in dense monoculture stands that can negatively affect wetland plant diversity (Tuchman et al. 2009, Travis et al. 2010, Larkin et al. 2011, Marburger and Travis 2013). Although effects of *T. × glauca*'s encroachment on native plants and wetland structure have been well-established, less is known of its possible effects on native wildlife (Tuchman et al. 2009, Travis et al. 2010, Larkin et al. 2011, Marburger and Travis 2013).

Common loon (*Gavia immer*; henceforth, "loons") is a large piscivorous waterbird (3.2–5.2 kg) and an iconic species in boreal lakes and lacustrine wetlands where *T. × glauca* is rapidly establishing (Piper et al. 1999, Windels et al. 2013). Loons are important predators in aquatic food webs and rely on high-quality habitats to forage and reproduce (Piper et al. 1999, McCarthy and DeStefano 2010, Radomski et al. 2014). The littoral zone serves as vital foraging areas for loons as they hunt for yellow perch (*Perca flavescens*), pumpkinseed (*Lepomis gibbosus*), and bluegill (*Lepomis macrochirus*; Strong and Bissonette 1989, Ruggles 1994, Evers 2007). Prey-rich waters are critical for obtaining necessary caloric input, which can be in excess of 423 kg of fish for a loon family (2 adults, 2 chicks) in a single breeding season (Barr 1996, Evers 2007). These areas can provide loons with an abundance of prey and sufficient foraging areas for pursuit of highly mobile and erratic prey (Strong and Bissonette 1989, Ruggles 1994, Barr 1996, Evers 2007).

It is plausible that expanding *T. × glauca* populations could negatively affect habitat quality for common loons; however, this hypothesis has not yet been evaluated. Although *T. × glauca* reduces open-water area in wetlands, potentially reducing loon foraging areas, loons often construct floating nests made of emergent vegetation, including cattail litter,

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which suggests a potential positive effect of abundant *T. × glauca* stands (Mathieson 1969, DeSorbo et al. 2006, Windels et al. 2013). Thus, the relationship between loons and *T. × glauca* remains unclear.

Our goal was to quantify effects of *T. × glauca* encroachment on habitat use by loons in a representative lake ecosystem. If expanding *T. × glauca* populations limit the spatial distribution of loons, we expected lower habitat occupancy rates at sites with abundant *T. × glauca* coverage. We also predicted site occupancy probabilities by loons would be greater in deeper water and reduced submergent vegetation because these areas likely provide better foraging opportunities.

STUDY AREA

Our study was focused in Rainy and Kabetogama lakes in northern Minnesota, USA (48.6026°N, -93.40365°E; Fig. 1). Both lakes were located on the United States–Canada border with portions of each falling within the boundaries of Voyageurs National Park (VNP; 88,300 ha; Fig. 1). Our study area occurred in the boreal ecosystem characterized by warm, humid summers (\bar{x} temp = 17°C) and cold, dry winters (\bar{x} temp = -13°C) with a mean annual precipitation level of 62 cm (Kallemeyn et al. 2003, NOAA 2016). Shorelines and littoral zones of both lakes were dominated by mats of *T. × glauca* with small patches of common water reed (*Phragmites australis*), wild rice (*Zizania* spp.), and bulrush (*Schobenopectus acutus*) dispersed throughout (Kallemeyn et al. 2003, Windels et al. 2013). Both lakes contained hundreds of small islands and wetlands that serve as potential nesting habitat for waterbird species including loons (Windels et al. 2013; Fig. 1). Dams at the outlets of both lakes maintained dynamic water levels, with annual peak water levels in Rainy Lake and Kabetogama Lake around 1 June and 1 July, respectively (Kallemeyn et al. 1993, Windels et al. 2013). Native broad-leaf cattails were extremely rare in VNP and recent research suggested

T. × glauca was the dominant cattail species in the region (Travis et al. 2010, Marburger and Travis 2013).

METHODS

Data Collection

We sampled 71 sites within Rainy and Kabetogama lakes to assess the presence or absence of loons. We used a digital vegetation map of VNP (based on the National Vegetation Classification System; Faber-Langendoen et al. 2007) to identify all wetlands adjacent to Rainy and Kabetogama lakes and delineated these areas as unique polygons in ArcMap 10.4 (ESRI 2015). We randomly selected unique polygons to sample and ground-truthed each to ensure they occurred in wetland habitats. We then established our sampling sites on the general centroid of each randomly selected wetland polygon ($n=71$; Fig. 2). Sites were separated by a mean Euclidian distance of 1,247 m (SD = 377 m) and a *post hoc* analysis determined that sites were distributed across a gradient of *T. × glauca* coverage (Fig. 3). We considered each site a resource patch (2 ha) because it was much smaller than the average loon home range (6–200 ha; Evers et al. 2010).

We determined loon occupancy at each site by repeated visual surveys conducted by 2 observers from 1 June 2016 to 6 August 2016. All surveys were conducted between 0700 and 1800. Observers accessed sites by a single motorized boat, stopped approximately 100 m from the centroid of each site, and visually searched for loons for 5 min using binoculars. If a loon was detected within the boundaries of our site by ≥ 1 observer during a site visit, the site was determined to be occupied. We conducted 3 visits to each site (i.e., one survey per visit) and separated each site visit by ≤ 1 week to ensure population closure (MacKenzie et al. 2006). Thus, our detection histories for each site included 3 primary sampling periods. Our total sampling effort included 213 independent surveys across 142 ha of wetland habitat.

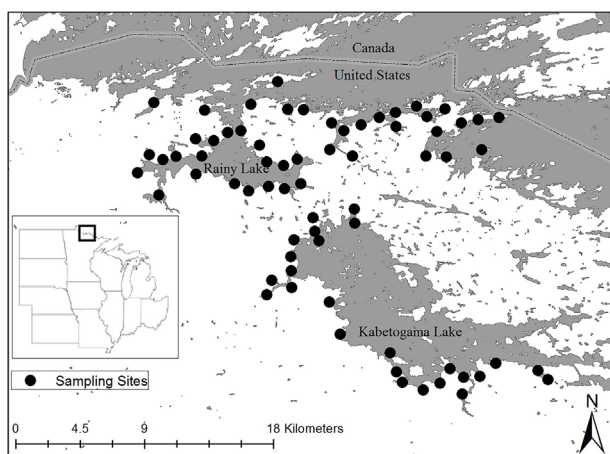


Figure 1. Sampling sites (dark circles; $n = 71$) used to assess common loon habitat occupancy in wetlands in Voyageurs National Park, Minnesota, USA. Each randomly selected site (2 ha) was considered a resource patch and sampled 3 times during the summer of 2016 for the presence or absence of common loons.

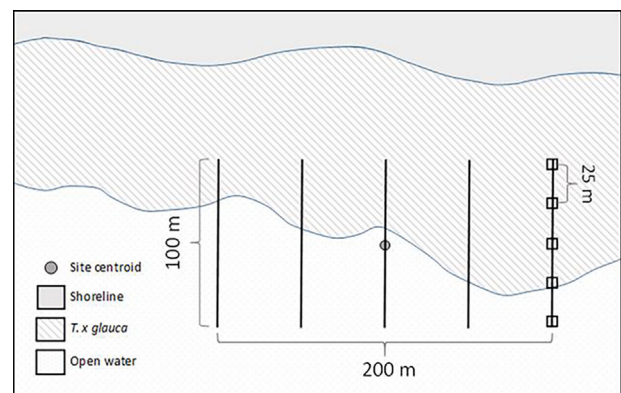


Figure 2. Schematic diagram of a wetland site used to assess common loon habitat occupancy and measure site-level habitat variables in Voyageurs National Park, Minnesota, USA, during 2016. Vertical lines represent common loon habitat sampling transects. Small boxes positioned on the right transect show habitat sampling points along each transect. Patterns represent the location of upland shoreline, extent of *Typha × glauca* encroachment, and open water.

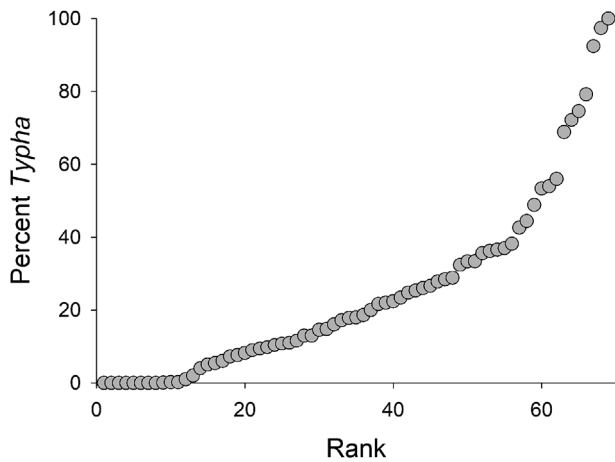


Figure 3. Distribution of wetland sites ($n = 71$) sampled for common loon occupancy in Minnesota, USA, during the summer of 2016, ranked by percent of $T \times glauca$ coverage at each site.

We measured several survey-specific variables that could potentially affect our ability to detect loons. We expected greater loon detection probabilities on days with greater relative ambient air temperatures, low wind speeds, clear skies, and no precipitation. We measured temperature ($^{\circ}\text{C}$), wind speed (km/hr), and direction using a hand-held device (Kestrel[®] 2500, Nielsen-Kellerman, Boothwyn, PA, USA). We quantified cloud cover as the percentage of sky that appeared cloudy and segregated these percentages into tenths (1 = no clouds, 10 = completely cloudy). We measured and recorded precipitation during the survey on a scale from 0 to 3 (0 = no precipitation, 3 = heavy precipitation).

We established 5 parallel transects (100 m long, each separated by 50 m), centered on the centroid of each site, to measure site-specific habitat variables that could be important for habitat selection by loons (Fig. 2). Transects were positioned perpendicular to the shoreline (Fig. 2). At 5 evenly spaced positions along each transect, we used a 1-m \times 1-m floating Daubenmire frame to estimate the percentage of $T. \times glauca$ coverage, percentage of open-water habitat, water depth (m), maximum vegetation height (m), substrate type (rocky, muddy, rocky-muddy, muddy-rocky), and coverage of other species-specific native plants (i.e., rushes, sedges, grasses). We calculated a mean for these measurements ($n = 25$) for each site to obtain a single site-level estimate for individual habitat covariates.

Data Analysis

We developed single-season occupancy models to assess the relative influence of our measured covariates on local-scale habitat occupancy by loons (Program PRESENCE 11.3; MacKenzie et al. 2006). Our candidate set of detection models ($n = 8$) included the single and additive effects of our survey-specific detection covariates along with a constant model. For our occupancy rate parameter, we considered a candidate set of models that included the single and additive combinations of all possible covariate combinations along with the intercept-only model ($n = 27$). Additionally, we included 5 models that investigated support for a potential

interaction between water depth and our measured site vegetation characteristics. We did not include covariates that were correlated ($|r| \geq 0.50$) within the same model. We assessed support for each model using Akaike's Information Criterion corrected for small sample sizes (AIC_c) and we evaluated the importance of each variable's inclusion in competitive models ($\Delta AIC_c \leq 2.00$) using an information theoretic approach (Burnham and Anderson 2002, Arnold 2010). We first selected the model that best explained loon detection and then subsequently fit single-season occupancy models that also incorporated our most-supported detection model (Ahlers et al. 2016).

RESULTS

We observed loons at 39 of 71 sites (naïve occupancy = 0.55). Based on our constant model of detection and occupancy, per-survey detection probabilities for loons was moderate ($\rho = 0.49$, $SE = 0.06$) and corrected site occupancy was 0.63 ($SE = 0.08$). Our top model of detection indicated that the time of day surveys were conducted (Time) influenced our ability to detect loons (Table 1). Detection probabilities for loons decreased later in the day (Time; $\beta = -0.0015$, $SE = 0.0003$; Table 1). Covariates "Wind" and "Day of the year" were also present in competitive models; however, based on the minimal change in model fit, it was likely they were uninformative parameters (Burnham and Anderson 2002, Arnold 2010). Thus, we used our "Time" detection model to fit subsequent single-season occupancy models.

Our most-supported model of loon occupancy included the single effect of water depth, suggesting occupancy probabilities were greater at sites with deeper water (Depth; $\beta = 4.89$, $SE = 1.80$; Table 1; Fig. 4). Additionally, models that incorporated the covariate "Depth" contributed to the majority of all model weights ($\sum w_{\text{Depth}} = 0.95$; Table 1). There were 4 other competitive models; however, none explained these data substantially better than our top-ranked model (differences in deviance values from all competitive models relative to the top model = 0.22–0.66; Table 1). Our other covariates, including "Typha," were likely benefitting by the effect of "Depth" (difference in deviance value of the "Depth + Typha" model from top model = 0.31; Table 1; Fig. 5) and were uninformative (Burnham and Anderson 2002, Arnold 2010). There was no support for models that included interactions between water depths and other measures of vegetation cover (Table 1).

DISCUSSION

Expansion of invasive hybrid cattail populations into North American wetlands is an immediate concern for land and wildlife managers. This novel landscape change necessitates information on species-specific sensitivities to encroaching nonnative vegetation. We found that our ability to detect loons in regions where $T. \times glauca$ is expanding is influenced by the time of day the survey was conducted. Our results also indicate that habitat use by loons is influenced more by water depth than encroachment by $T. \times glauca$, suggesting that loon distributions are relatively insensitive to expanding $T. \times glauca$ populations at the local scale.

Table 1. Competitive models that explain variation in detection and habitat occupancy by common loons in northern Minnesota, USA, in 2016. We ranked models by descending ΔAIC_c . w = model weight; K = number of estimable parameters in each model; Deviance = $-2(\text{Log Likelihood})$. Parameters in each model include: Time (time of day), DOY (day of the year), Wind (average wind speed), Depth (average water depth), Emerg (% emergent vegetation coverage), WoodyVeg (% woody vegetation coverage), Typha (% *T. x glauca* coverage), VegHeight (average vegetation height), SubVeg (% submergent vegetation cover), and Intercept only (model intercept). We only present models within $\Sigma w \geq 0.95$ for each rate parameter along with the Intercept only model.

Model	ΔAIC_c	w	K	-2Log Likelihood
Detection				
Time	0.00	0.40	3	243.77
Time + DOY	1.22	0.22	4	242.99
Time + Wind	1.96	0.15	4	243.73
Time + DOY + Wind	3.12	0.08	5	242.89
Intercept only	3.71	0.06	2	249.48
Wind	4.71	0.03	3	248.48
Occupancy				
Depth	0.00	0.23	4	229.27
Depth + Emerg	1.34	0.12	5	228.61
Depth + Typha	1.69	0.10	5	228.96
Depth + WoodyVeg	1.73	0.10	5	229.00
Depth + SubVeg	1.78	0.10	5	229.05
Depth + SubVeg + Depth \times SubVeg	3.08	0.09	6	228.35
Depth + WoodyVeg + Depth \times WoodyVeg	6.71	0.05	6	232.77
Depth + Emerg + Depth \times Emerg	6.82	0.05	6	232.88
Depth + VegHeight + Depth \times VegHeight	7.26	0.05	6	233.32
Depth + Typha + Depth \times Typha	8.06	0.04	6	236.12
Open Water + Typha	9.59	0.04	5	235.65
Intercept only	12.50	0.00	3	243.77

Our most-supported detection model suggests that loons were more apparent to observers earlier in the day. During the summer, adult loon activity varies according to their breeding and nesting habits (Nocera and Taylor 2000). Visible adult loon activity peaks prior to nesting as they consistently forage, but diminishes later in the summer as they dedicate most of their time to nest-sitting and, beginning posthatch, to resting and chick-rearing (Evers 1994). As expected, we detected loons more frequently earlier in the day because loons actively forage during this

time and are most vocally active from late evening to early morning (Evers et al. 2010, Mennill 2014).

We found a positive relationship between habitat occupancy by loons and water depth. The likelihood of a site being occupied by loons was greater at sites with deeper water. Within *T. x glauca* dominated sites (i.e., sites with $>50\%$ *T. x glauca* coverage), open-water habitat was generally ≤ 0.4 m deep, which may inhibit loons' foraging behavior (peering underwater, locating prey then diving in pursuit; McIntyre 1988, Banner and Schaller 2001). We

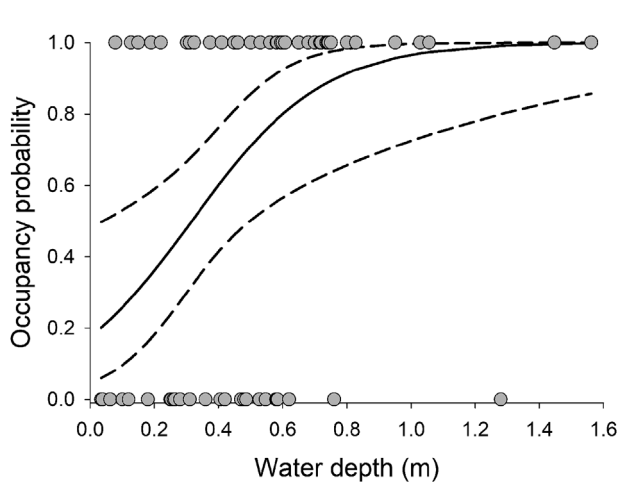


Figure 4. The relationship between water depth (m) and habitat occupancy probabilities by common loon at wetland sites ($n = 71$) in Minnesota, USA, during the summer of 2016. Occupancy estimates (solid line) and 95% confidence intervals (dashed line) were derived from our top-ranked single-season occupancy model (Table 1). Gray circles indicate naïve site occupancy (1 = occupied, 0 = absent) of common loons at sites with varying water depths.

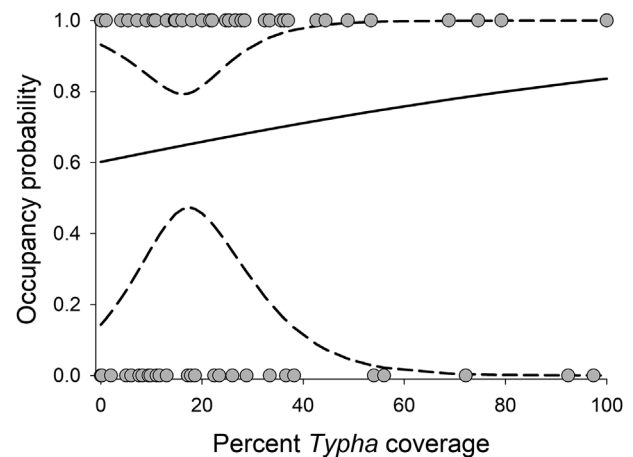


Figure 5. The relationship between percent *Typha x glauca* coverage and habitat occupancy probabilities by common loon at wetland sites ($n = 71$) in Minnesota, USA, during summer 2016. Occupancy estimates (solid line) and 95% confidence intervals (dashed line) were derived from a competitive single-season model (Depth + Typha; Table 1) while holding the covariate “Depth” constant at its median value. Gray circles indicate naïve site occupancy (1 = occupied, 0 = absent) of common loons along a gradient of *Typha x glauca* coverage (0–100%) of each site.

speculate that these shallow sites were less occupied because they lacked adequate depth to support pursuit-based foraging, which is important for successful summer survival and reproduction (Gadomski and Parsley 2005, Thompson and Price 2006).

Contrary to our hypothesis, loons did not avoid sites that were exposed to *T. × glauca* encroachment. The absence of a negative *T. × glauca* effect could be a result of an indirect positive effect related to the abundance of cattail litter or floating cattail mats useful for construction of nesting platforms (Mathieson 1969). Indeed, the probability of loon nest success is greater for nests that are positioned on floating mats or artificial floating platforms than those on shore (Mathieson 1969, Vermeer 1973, Windels et al. 2013). This effect is particularly relevant at VNP, which is marked by a dynamic hydrology brought on by active management for both hydropower and flood control (Windels et al. 2013). Abundant floating *T. × glauca* mats may mediate negative impacts of water-level changes by offering nesting substrate that can accommodate modest changes in water levels (Reiser 1988, Kallemeyn et al. 1993, Windels et al. 2013). It is possible that lakes with less dynamic hydrology regimes may experience differing relationships between *T. × glauca* coverage and loon distribution. Future research should focus on the potential interaction between human-modified hydrology and presence of *T. × glauca* on wetland-obligate species (e.g., waterbirds, semiaquatic mammals, amphibians).

Although our study suggests loons are tolerant of expanding *T. × glauca* populations, we acknowledge 2 caveats that may affect our interpretation of the results. First, because our study was limited to a local resource patch-use scale (2 ha) and single season and year (summer 2016), it may not reveal patterns occurring at larger spatiotemporal scales. However, our study does provide a snapshot of patterns likely emerging during a critical life history stage for loons. Second, aggressive expansions of *T. × glauca* results in dense monocultures in exposed wetlands. Under some conditions, loons could experience a threshold-related response in which occupancy and other vital rates may become negatively affected by extreme levels of cattail coverage (i.e., 90–100%). Our sampled wetland sites included few wetlands that were completely dominated by *T. × glauca*, so we may have been unable to detect this effect. Future studies should work to uncover potential thresholds of *T. × glauca* coverage on demographic rates of loons.

Voyageurs National Park has recently started a management program to treat *T. × glauca*-invaded wetlands in the park's large lakes. Our results suggest that targeted removal of *T. × glauca* in wetlands may promote increases in the amount of habitat with sufficient water depth to support loon foraging and result in an increase in overall available habitat for loons at VNP. Past research has documented that floating mats of *T. × glauca* are sometimes used as nesting structures by loons; therefore, park managers should consider leaving small patches of floating cattails in areas where loon production is often poor. We

suggest basic and applied studies to investigate how *T. × glauca* removal techniques (e.g., cutting, dredging, burning) and intensity of removal patterns (e.g., complete eradication vs. leaving residual patches of cattails) affect demographic rates of loons and other wetland-obligate species.

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